Simulating Peer Disagreement in Cosmology

Sebastián Gil Rodríguez*

July 16, 2019

Peer Disagreement

How should we rationally respond to disagreement on a given issue? In particular, how should *epistemic peers* respond to a disagreement within their shared domain of expertise? Because scientific communities are usually composed of individuals who have undergone similar training, peer disagreement is of particular relevance to the study of disputes among scientists. One proposed resolution is for the individuals to *split the difference*. If two epistemic peers are exposed to the same evidence and find themselves in disagreement with each other, they should take a weighted average of their opinions and adjust their beliefs accordingly. Individuals may choose to assign a higher weight to their own opinion and a lower weight to that of their peers, but they would be forced to justify their choices of weights.

To circumvent this need for justification, the *Equal Weight View* has been proposed as a rational course of action in light of peer disagreement.[1] If both experts are equally competent in their assessment of the evidence and still end up disagreeing, the Equal Weight View requires them to take the arithmetic average of their opinion. Thus, for example, if Scientist A has a degree of belief in hypothesis H of 0.2 and Scientist B has a degree of belief of 0.8 in the same hypothesis, they would both be required to adjust their degree of belief to 0.5 under the Equal Weight View. In particular, proponents of the Equal Weight View argue that its validity can be established in an *a priori* manner, and that it is irrational to refuse to split the difference with one's epistemic peers.

Simulating Peer Disagreement

Identifying this thesis as the *Irrationality Claim*, Igor Douven addresses his 2010 paper to dispute its validity by means of an agent based model.[2] His analysis is based on computer simulations of the Hegselmamn-Krause Model for "opinion dynamics of communities of agents who are individually trying to determine the value of a certain parameter."[3] Because the agents in the model are trying to arrive at the true value of a parameter, this model is best-suited to describing peer disagreement among scientists trying to measure a constant of nature. In Douven's implementation of the Hegselmann-Krause model, the opinion of an agent x_i after the $u-$th update is determined by the equation

$$x_i(u+1) = \alpha \frac{1}{|X_i(u)|} \sum_{j \in X_i(u)} x_j(u) + (1-\alpha)(\tau + \mathrm{rnd}(\zeta)) \tag{1}$$

*Munich Center for Mathematical Philosophy, Matrikelnummer: 12011085

1. Adam Elga, "Reflection and Disagreement," *Noûs* 41, no. 3 (2007): 478–502.
2. Igor Douven, "Simulating Peer Disagreements," *Studies in History and Philosophy of Science Part A* 41, no. 2 (2010): 148–157.
3. Ibid., p.149.

whereby

$$X_i(u) := \{j : |x_i(u) - x_j(u)| \leq \varepsilon\} \tag{2}$$

constrains the number of peers that an agent is willing to “listen to” when updating its opinion. This model depends on four parameters:

1. the true value $\tau \in (0, 1]$
2. the symmetric confidence interval generated by $\varepsilon \in [0, 1]$
3. the weighing factor $\alpha \in [0, 1]$, and
4. a noise value drawn from the uniform distribution $[-\zeta, \zeta]$ for some parameter $\zeta \in [0, 1]$

The core of Douven’s analysis relies on comparing simulation results for no difference-splitting communities ($\alpha = 0.5$, $\varepsilon = 0.1$) and difference-splitting communities ($\alpha = 0.9$, $\varepsilon = 0.1$) for fixed values of τ and ζ. His main finding is that, in the presence of noisy data, the no difference-splitting communities get relatively close to the true value of τ after a few updates with no further improvement over time. Conversely, the difference splitting communities take much longer to get closer to the true value of τ but end up being much more accurate upon doing so. Douven concludes that “the main lesson to be learned from the simulations we have looked at is that what it is best to do in cases of disagreement with peers may depend on circumstances the obtaining of which is neither general nor a priori.”[4]

Proposed Model

In a 2018 publication, Frey and Šešeja argue that taking the results of agent based model (ABM) simulations as informative of actual scientific inquiry is unwarranted unless the models are subjected to some form of robustness analysis.[5] An ABM may exhibit robustness under two types of changes: first, if its results remain stable under changes in the paramater space over which the model is designed; and second, if the results remain stable under a change in the idealizing assumptions of the model. The aim of my project is to perform a robustness analysis of Douven’s results by modifying both the parameter space and the idealizing assumptions of his implementation of the Hegselmann-Krause model.

I will tailor my simulation to model peer disagreement in an actual domain of scientific inquiry: Hubble constant measurements of the rate of expansion of the universe in physical cosmology. I will focus on the discrepancy between the value of 67.66 ± 0.42 (km/s)/Mpc derived from the anisotropy measurements of the cosmic microwave background on one hand, and the value of 74.04 ± 1.42 (km/s)/Mpc derived from luminosity measuremends of Cepheid variable stars

4. Douven, “Simulating Peer Disagreements,” p.156.

5. Daniel Frey and Dunja Šešelja, “What Is the Epistemic Function of Highly Idealized Agent-Based Models of Scientific Inquiry?,” *Philosophy of the Social Sciences* 48, no. 4 (2018): 407–433.

located in the galaxies closest to our own.[6][7] Both methods rely on completely different sets of assumptions which have nonetheless produced the most accurate observations to date within their respective domains of application. The key difference is that the first value is based on observations of the early universe whereas the second value is based on observatoins of the late universe. This discrepancy may very well be indicative of new physics beyond the current standard model of cosmology. However, before Douven's model can be applied to this real-world scenario of peer disagreement, it must be modified in a number of ways.

First, note that all parameters chosen by Douven are drawn from the real number value interval $[0, 1]$, which presupposes that they are normalized with respect to some metric. However, besides the weighing factor α, there is no empirical reason why all other model parameters should be constrained to this interval other than an arbitrary choice of the author. I identify this arbitrariness with a basic failure to specify real measurable quantities over which the model parameters are defined. Because physical cosmology is a science employing the strictest statistical controls, it is possible to assign τ, ζ, and ε intervals drawn from the physical parameter space defined by the telescopes used by the two teams of astronomers.

Second, I would like to follow through on Douven's analysis of the idealizing assumptions of the Hegselmann-Krause model by taking a more rigorous treatment of his proposed modifications. Specifically, Douven considers separately a scenario in which agents' opinions are penalized according to a scoring rule and a scenario in which they randomly alternate between pure data collection and opinion pooling. Instead of having agents randomly switch strategies, I propose to have my agents switch from a pure data collection strategy to a difference splitting strategy once their penalties pass a certain threshold.

Third, in order to honor the distinct methodologies used to measure the Hubble constant, agents will only collect data with respect to the τ and ζ values of their *assigned telescope*. This will cleanly separate the evolution of the ABM into an *observation stage* and a *conference stage*. As noted by Adam Riess, the discrepancy between the value of the Hubble constant measured by his collaboration and that measured by the Planck collaboration can be resolved if the latter group considers new physics beyond the standard model of cosmology.[8] In the context of my model, such changes can be reflected by modifying the ε value of agents during the conference stage. Possibly, such a modification can be implemented by means of a meta-statistical scoring rule such as that considered by Mayo and Spanos or, alternatively, by Foster and Sober.[9][10]

In closing, I hope through this project to bridge the gap between classes

6. Planck Collaboration et al., "Planck 2018 results. VI. Cosmological parameters," *arXiv e-prints*, July 2018,

7. Adam G. Riess et al., "Large Magellanic Cloud Cepheid Standards Provide a 1% Foundation for the Determination of the Hubble Constant and Stronger Evidence for Physics beyond ΛCDM," *The Astrophysics Journal* 876, no. 1, 85 (May 2019): 85.

8. Ibid., p.22, Fig.4.

9. Deborah G. Mayo and Aris Spanos, "Severe Testing as a Basic Concept in a Neyman–Pearson Philosophy of Induction," *British Journal for the Philosophy of Science* 57, no. 2 (2006): 323–357.

10. Malcolm Forster and Elliott Sober, "How to Tell When Simpler, More Unified, or Less Ad Hoc Theories Will Provide More Accurate Predictions," *British Journal for the Philosophy of Science* 45, no. 1 (1994): 1–35.

of ABM models that are too idealized and communities of natural scientists that are indifferent to results from the social scientists. If Douven's results are found to be robust under the proposed change of parameters, cosmologists may be able to justify their resistance to splitting the difference with their peers. Alternatively, if the model shows a parameter regime in which agents converge to a new intermediate value of the Hubble Constant, this might offer some epistemological constraints on new physics beyond the standard model of cosmology.

References

Douven, Igor. "Simulating Peer Disagreements." *Studies in History and Philosophy of Science Part A* 41, no. 2 (2010): 148–157.

Elga, Adam. "Reflection and Disagreement." *Noûs* 41, no. 3 (2007): 478–502.

Forster, Malcolm, and Elliott Sober. "How to Tell When Simpler, More Unified, or Less Ad Hoc Theories Will Provide More Accurate Predictions." *British Journal for the Philosophy of Science* 45, no. 1 (1994): 1–35.

Frey, Daniel, and Dunja Šešelja. "What Is the Epistemic Function of Highly Idealized Agent-Based Models of Scientific Inquiry?" *Philosophy of the Social Sciences* 48, no. 4 (2018): 407–433.

Mayo, Deborah G., and Aris Spanos. "Severe Testing as a Basic Concept in a Neyman–Pearson Philosophy of Induction." *British Journal for the Philosophy of Science* 57, no. 2 (2006): 323–357.

Planck Collaboration, N. Aghanim, Y. Akrami, M. Ashdown, J. Aumont, C. Baccigalupi, M. Ballardini, et al. "Planck 2018 results. VI. Cosmological parameters." *arXiv e-prints*, July 2018.

Riess, Adam G., Stefano Casertano, Wenlong Yuan, Lucas M. Macri, and Dan Scolnic. "Large Magellanic Cloud Cepheid Standards Provide a 1% Foundation for the Determination of the Hubble Constant and Stronger Evidence for Physics beyond ΛCDM." *The Astrophysics Journal* 876, no. 1, 85 (May 2019): 85.